Publishing Patterns and Core Journals of the "Nano" Research Front

Cynthia G. Manley, MLS
Research Librarian, Oak Ridge National Laboratory

Teresa S. Welsh, Ph.D.
Assistant Professor, University of Southern Mississippi
School of Library & Information Science

Introduction

BACKGROUND – WHAT IS A NANO?

A nanometer is one *billionth* of a meter – equal to the *width of a single strand of DNA or 1/100,000 the width of a human hair* – making nano objects too small to view with the naked eye.

Technology plays a significant role in society and is dramatically changing modern daily life. The desire for smaller and faster electronic and other devices has lead to a continually increasing interest in the miniaturization of physical things to the smallest possible scale.

When the term "nanotechnology" was coined in the 1980s, it heralded the beginning of a new wave of research. The coining of the term 'nanotechnology' is credited to Eric Drexler.[1] In his book *Engines of Creation*, he predicted that nanotechnology could give rise to replicating assemblers at a microscopic level, permitting an exponential growth of productivity and personal wealth.[2]

Interest in nanoscale phenomena has become the focus of researchers and manufacturers around the world because the behavior of materials at the nanoscale is different than at the large scale. Many scientists and researchers believe that nanotechnology will create the next industrial revolution because it has the potential to fundamentally change manufacturing, communication, medicine, and information storage and processing. This revolutionary prospect of being able to build things atom-by-atom can only be achieved if researchers are able to understand the special rules that govern behavior at the small scale and develop the knowledge needed to integrate these concepts into practical devices.

NANO LEGISLATION

Recent legislation is one indication that the nano field is an emerging frontier of science. In 2001, the Clinton administration supported the foundation of the National Nanotechnology Initiative (http://www.nano.gov/) as a federal research initiative. Its goal was to provide financial support to a long-term nanoscale research and development agenda in areas such as materials, manufacturing, medicine, environment, chemistry and agriculture.[3]

President Bush signed the "21st Century Nanotechnology Research and Development Act" (www.theorator.com/bills108/s189.html) in 2003 and has continued to support the fundamental nanotechnology research agenda that began in the previous administration. The US government has shown its support for this research to the tune of 3.7 billion over the next four years.[4] This federal effort promotes a research infrastructure that has influenced the growth of nanoscale research activity.

PURPOSE OF THE STUDY

One of the intriguing problems of modern science is understanding how new areas of scientific research evolve. According to Goffman,[5] most scientists at one time or another have given thought to how particular areas of research have grown and developed. Studying the growth of scientific literature has been a staple in the field of information science and bibliometric techniques are typically employed to study the growth and dispersion of the literature of a particular topic.

Scholarly literature serves as one of the major communication channels for reporting scientific research. Therefore, it is useful to employ bibliometric methodology to document a timeline of scholarly nano publications, to trace the evolution of the terminology 'nanoscience' and 'nanotechnology' in the research literature, and to identify core journals of the nano research front.

RESEARCH QUESTIONS

1) What are the publication patterns of the literature of nanoscience and of nanotechnology?

2) What are the origins and evolution of the terms "nanoscience" and "nanotechnology" in the nano literature?

3) What are the core journals of nanoscience and nanotechnology?

DEFINITIONS

Bibliometrics

> Bibliometrics is "the use of mathematical and statistical methods to study the usage of materials and services within a library or to analyze the historical development of a specific body of literature, particularly its authorship, publication, and use."[6]

Citation Analysis

> A citation, the acknowledgement that one document receives from another, implies a relationship between documents. "Citation analysis is that area of bibliometrics that deals with the study of the relationship between cited and citing documents."[7]

LIMITATIONS

The prefix 'nano' has been applied broadly to science and technology and covers a wide variety of disciplines ranging from physics and chemistry to biology and medicine. This study was limited to English language documents, primarily journal articles, indexed in major scientific databases that are related to nanoscience and nanotechnology.

ASSUMPTIONS

It is assumed that the articles in the various databases in this study were indexed accurately so that pertinent items could be retrieved in a consistent manner using the same queries.

Smith (1981) notes that while citation analysis is valued for its unobtrusiveness, preciseness, and objectiveness, it also contains an implicit set of assumptions about the nature of citations:

1. Citation implies use of the cited document by the author;
2. Citation implies that the document cited has merit or impact and that citations are made to the most relevant works on the subject;
3. Citation implies the cited and citing documents are related in content;
4. All citations are equal and are counted equally;
5. Citations are accurately indexed.[8]

Literature Review

BIBLIOMETRICS

The meaning of bibliometrics is literally the measurement of books or documents and their characteristics. White and McCain (1989, 119) defined the task of bibliometrics as "to provide evolutionary models of science, technology, and scholarship. Distinctly, it construes these worlds as realized over time through publications…"[9]

One type of bibliometric research is the analysis of the historical development of a specific body of literature, a 'literature of' study. According to Smith, in the 1981 article "Citation Analysis," 'literature of' studies may include types, age, highly cited authors and journals, languages and/or countries of origin, and subject distribution.

One example of a "literature of" study is Susan Davis Herring's journal article (2000) that examines publishing and indexing patterns of the literature on digital libraries to identify the core journals and descriptor terms. Results indicate no core journals and inconsistent indexing for this multidisciplinary topic.[10]

In a 2003 article by Pelzer and Wiese, "Bibliometric Study of Grey Literature in Core Veterinary Medical Journals," bibliographic citations from twelve core veterinary journals published in 2000 were analyzed to determine the proportion of citations from grey literature. Results indicate that about 6 percent of the bibliographies were grey literature citations with 90 percent of those being conference papers, government publications, and corporate literature.[11]

"The Literature of Telemedicine: A Bibliometric Study" by Welsh (2004) examined the publishing and citing pattern of telemedicine literature indexed by the Telemedicine Information Exchange (TIE) database. Results of the study indicate a yearly increase in the number of telemedicine items published from 1960 to 1999, with 70 percent published since 1995 and 86 percent published since 1990. Two peer-reviewed highly cited telemedicine journals, *Journal of Telemedicine and Telecare* and *Telemedicine Journal*, were identified as core journals of this specialized field.[12]

RESEARCH FRONTS

According to Eugene Garfield emergent research fronts are hot areas of research that "reflect the current preoccupations of mainstream natural and social sciences" and are associated with a core of highly cited publications.[13]

"Research Front Methodology" by ISI (http://www.esi-topics.com/RFmethodology.html) states that research front analysis "does not identify all research areas or all the papers in an area. However, it can assist in identifying areas where important work is being done and where the scientific community is focusing its attention." The publication patterns of a cutting-edge research fronts, including distribution of papers by year, can indicate the growth and development of specialized fields of study. Analysis of document characteristics can identify highly cited or core papers, authors and journals.[14]

In a 1990 book, *Scholarly Communication and Bibliometrics*, Brooks authored a chapter titled, "Core Journals of the Rapidly Changing Research Front of Superconductivity." Brooks identified the core journals of superconductivity using bibliometric methodologies.[15] In a similar journal article, "Literature Core Zones Adjusted by Impact Factors," Brooks (1990) reported the effect of adjusting the frequency of occurrence of journals (Bradford's Law, which states a relatively small number of core journals will contain approximately one-third of all the scholarly articles published on a particular topic) with impact factors in the literatures of acid rain, superconductivity and management by objectives.[16]

Persson (1994), in "The Intellectual Base and Research Fronts of *JASIS* 1986–1990," conducted a citation analysis of 209 articles published in the *Journal of the American Society for Information Science* to compare the intellectual base and the research front. Persson defined intellectual base as a cluster of co-cited articles (co-citation is defined as the number of times articles or authors appear together in the same reference lists of papers). He determined the intellectual base of the *JASIS* articles by visually mapping clusters of co-cited authors and defined a research front as articles that cite the same core literature, in other words, a cluster of similar citing articles. He determined *JASIS* research fronts by mapping articles with at least five shared cited authors. Results of the analysis indicated a similarity with visual mapping of information science produced by other methods and a close correspondence between the research front map and the intellectual base map.[17]

Methodology

To gain an indication of the publication patterns of nanoscience and nanotechnology documents and trace the origins of the terminology, it was first necessary to identify the most relevant databases to search. Preliminary searches were conducted in Dialog DialIndex (file 411, then SF ALLSCIENCE) and SciFinder for the subject term 'nanoscience OR nanotechnology'. Four relevant databases were identified: Inspec with 11,921 items; Chemical Abstracts with 6,576 items; Ei Compendex with 6,602; and SciSearch Citation Index™ with 2,387 items.

> **INSPEC**, one of the world's largest bibliographic databases, covers the fields of physics, electrical engineering and electronics, computers and control engineering and information technology stretching from 1969 to the present.

Chemical Abstracts, published by CAS® (Chemical Abstracts Service), is a database that includes over 17 million citations to the worldwide literature of chemistry and its applications from 1967 forward.

Ei Compendex, a comprehensive bibliographic database of engineering research, covers the broad subject areas of engineering and applied science from 1969 to the present. Specifically, it includes the fields of nuclear technology, bioengineering, transportation, chemical and process engineering, light and optical technology, agricultural engineering and food technology, computers and data processing, applied physics, electronics and communications, control, civil, mechanical, materials, petroleum, aerospace and automotive engineering.

The Science Citation Index Expanded™ provides access to current and retrospective bibliographic information, author abstracts, and cited references found in approximately 5,900 of the world's leading scholarly science and technical journals covering more than 150 disciplines. The online version *SciSearch*® is available through Dialog or ISI's Web of Science or Web of Knowledge.

Literature in a rapidly developing field or research front such as nanotechnology is often characterized by a lack of well-defined subject headings or widely accepted operational definitions. While some use the terms 'nanoscience' and 'nanotechnology' interchangeably, Drexler discourages confusing scientific nanoscale research with the more pragmatic goal of molecular manufacturing with nanotechnology (http://www.nanotec.org.uk/evidence/15EricDrexler.htm).

The four identified databases were each first queried with the term 'nanoscience' and then with the term 'nanotechnology' in all subject words. The search was limited to English language documents by year starting with the year 2004 and working backwards until no further items were retrieved. For accuracy, the "remove duplicates" option was selected after each search and results were compiled in an Excel spreadsheet.

A frequency table of term occurrences by year was constructed for the results of each database search. A line graph illustrates the pattern over time for the literature in each of the databases.

Publication counts of cited and citing journals within the nano literature are one indicator in identifying core journals in the field. *Journal Citation Reports* was queried with the term 'nano' to retrieve specialized journals with nano in the title, then citation rates and impact factors were compared.

SciSearch® citation index database was queried for the term 'nanoscience' and then queried for the term 'nanotechnology.' The results were sorted by impact factor to identify the most cited articles and journals. Numeric results were compiled in an Excel spreadsheet and lists of most cited authors and journals were complied using Word word-processing software.

Results

PUBLICATION PATTERNS

Examining the growth of scientific literature has been a staple in the field of information science and bibliometric techniques are typically employed to study the growth of the literature of a particular topic and its dispersion. An interest in how to identify emerging research fronts led to analysis of publishing patterns in the field of nano research.

An examination and visualization of the publishing patterns identified using the term "nanoscience" and the term "nanotechnology" as separate search terms in multiple databases indicated a research front timeline for each term. Time lines are potentially useful tools in identifying the evolution of new research fronts.

Restatement of Research Questions

1) What are the publication patterns of the literature of nanoscience and nanotechnology?

2) What are the origins and evolution of the terms “nanoscience” and “nanotechnology” in the nano literature?

3) What are the core journals of nanoscience and nanotechnology?

Nanoscience

The earliest document retrieved in this study using the search term ‘nanoscience’ in all subject words was the 1991 article, “Crystallization of an Inorganic Phase Controlled by a Polymer Matrix,” by Bianconi, Lin, and Strzelecki, published in *Nature*.[18]

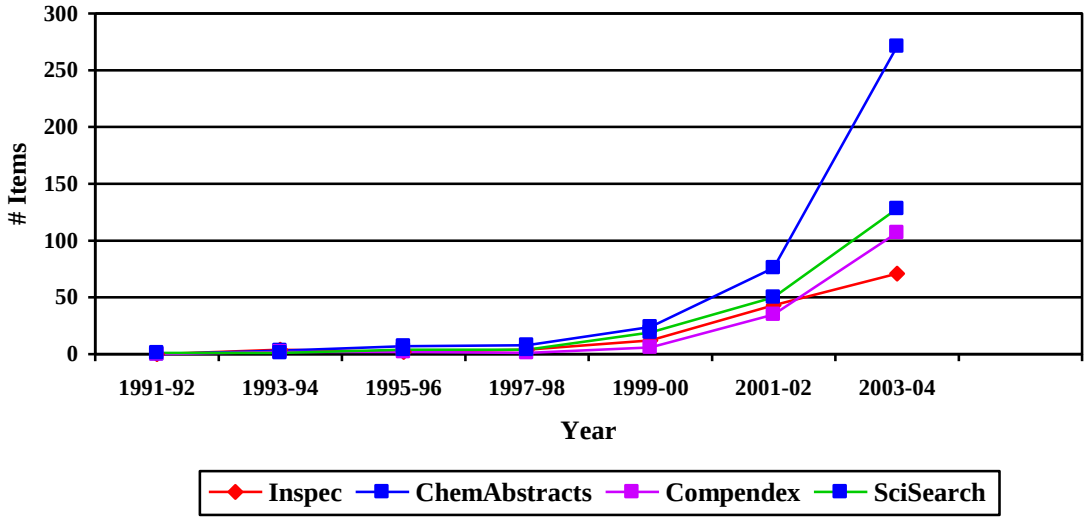
Table 1 indicates a pattern of growth of the number of nanoscience documents retrieved in this study from 1991, the year of the earliest document retrieved, through 2004.

Figure 1 illustrates the pattern of growth in the number of nanoscience documents in each of the databases by year.

Table 1. Nanoscience Items by Database and Year

Year	**Inspec**	**Chemical Abstracts**	**Ei Compendex**	**SciSearch® Citation Index**
2004	36	149	55	70
2003	35	122	52	58
2002	32	48	24	29
2001	11	28	11	21
2000	8	17	5	10
1999	4	7	1	9
1998	3	7	1	3
1997	1	1	0	1
1996	2	5	1	3
1995	0	2	1	1
1994	1	1	1	0
1993	3	2	1	1
1992	0	0	0	0
1991	0	0	0	1
Total	136	389	153	207

Figure 1. Nanoscience Publication Pattern by Database and Year



Nanotechnology

The earliest document retrieved in this study using the search term 'nanotechnology' in all subject words was the 1986 article, "Current Conditions and Future Perspectives of 3-Dimensional Nanotechnology" by Morimura in *Journal of the Society of Instrument and Control Engineers.*[19] This was the also the year (1986) that Eric Drexler, who is generally credited with coining the term 'nanotechnolog, published his classic book, *Engines of Creation.*

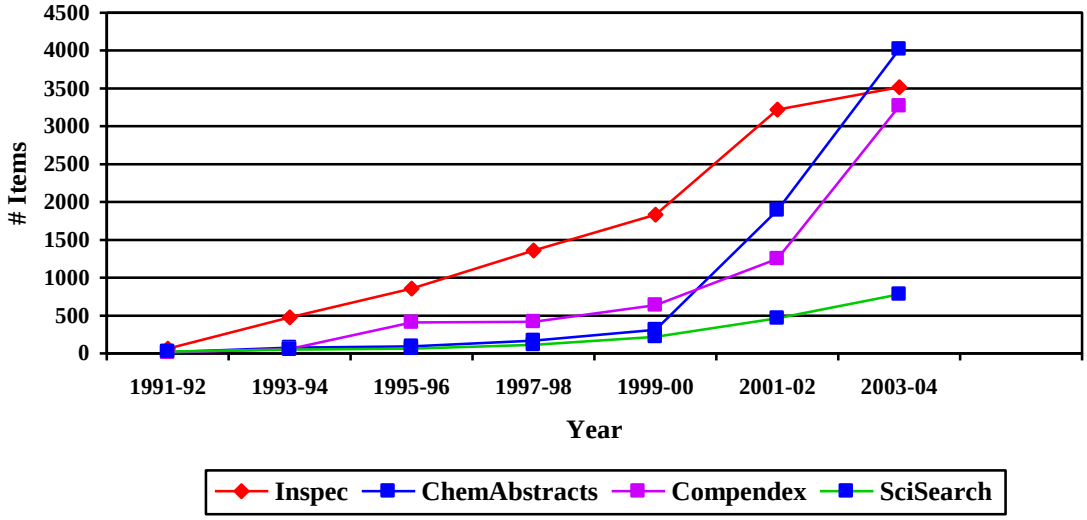
Table 2 indicates a pattern of growth of the number of nanotechnology documents retrieved in this study from 1986, the date of the earliest document, through 2004.

Figure 2 illustrates the pattern of growth in the number of nanotechnology documents in each of the databases by year.

Table 2. Nanotechnology Items by Database and Year

Year	**Inspec**	**Chemical Abstracts**	**Ei Compendex**	**SciSearch® Citation Index**
2004	1883	1990	1912	642
2003	1632	2029	1356	489
2002	1794	1324	781	291
2001	1429	567	470	172
2000	994	214	341	133
1999	839	100	296	87
1998	777	98	219	72
1997	583	70	198	40
1996	480	63	226	37
1995	379	29	183	27
1994	263	46	44	33
1993	215	28	13	17
1992	36	8	7	9
1991	28	8	7	16
1990	7	0	3	3
1989	2	0	0	0
1988	6	2	3	3
1987	3	0	1	0
1986	1	0	0	0
Total	11,351	6,576	6,060	2,071

Figure 2. Nanotechnology Publication Pattern by Database and Year



CORE JOURNALS

Specialized Nano Journals

To identify emerging specialty journals in the nano field, a search of ISI's *Journal Citation Reports, Science Edition* (online version) for 'nano' was conducted. The search retrieved the titles of three specialized nano journals (Table 3).

Table 3. *JCR* Nano Journal Titles and Impact Factors

Journal Title	2001 Cites*	Impact Factor
NANOTECHNOLOGY	691	1.621
NANOSTRUCTED MATERIALS	1795	0.969
PRECISION ENGINEERING: JOURNAL OF THE INTERNATIONAL SOCIETIES FOR PRECISION ENGINEERING & NANOTECHNOLOGY	336	0.408

*Cites by other peer-reviewed publications indexed by ISI

Impact Factor[20] = Cites in 2001 to articles published in 2000 / Number of articles published in 2000

Two additional nano journals were identified in SciSearch® but not yet indexed in *JCR*:

Journal of Nanoscience and Nanotechnology
Journal of Nanoparticle Research

Highly-Cited Core Journals

Publication counts of cited journals within the nano literature are used as one indicator in identifying core journals in the field. ISI published a list of 25 highly cited nano journals for the years 1991-2000 ranked by total number of cites (Table 4).[21]

Table 4. ISI Highly Cited Nano Journals, 1991-2000

	Title	# Cites	# Papers	Cites per Paper
1	SCIENCE	13341	237	56.29
2	APPLIED PHYSICS LETTERS	12586	1132	11.12
3	NATURE	11312	192	58.92
4	PHYSICAL REVIEW B	9525	820	11.62
5	PHYSICAL REVIEW LETTERS	8023	424	18.92
6	JOURNAL OF PHYSICAL CHEMISTRY	6422	182	35.29
7	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY	5582	270	20.67
8	JOURNAL OF APPLIED PHYSICS	5415	825	6.56
9	CHEMISTRY OF MATERIALS	5392	405	13.31
10	NANOSTRUCTURED MATERIALS	4893	1099	4.45

A list of highly cited nanoscience documents indexed in SciSearch® Citation Index was compiled and the five journals in which they were published ranked by record count of *highly cited* nanoscience articles (Table 5).

Table 5. Highly Cited Nanoscience Journals, 2001-2004

	Source Title	# Articles
1	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	13
2	JOURNAL OF NANOPARTICLE RESEARCH	12
3	CHEMICAL & ENGINEERING NEWS	6
4	CHIMIA	5
5	MATERIALS SCIENCE & ENGINEERING C-BIOMIMETIC AND SUPRAMOLECULAR SYSTEMS	4

A list of highly cited nanotechnology documents indexed in SciSearch® Citation Index was compiled and the five journals in which they were published ranked by record count of *highly cited* nanotechnology articles (Table 6).

Table 6. Highly Cited Nanotechnology Journals, 2001-2004

	Source Title	# Articles
1	ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY	59
2	NANOTECHNOLOGY	44
3	IEEE TRANSACTIONS ON NANOTECHNOLOGY	36
4	JOURNAL OF NANOPARTICLE RESEARCH	36
5	NATURE	32

Discussion

Results from this study provide a visual pattern of the evolution and growth of nanoscience and nanotechnology research.

Several things seem to be apparent from the publication patterns of the data retrieved for this study. Before 1990, there were less than 10 items published for either term in the databases examined in this study. In the 1990s, growth of the published literature accelerated and since 2000, there has been an even greater increase in the number of publications indexed with the terms 'nanoscience' as well as the term 'nanotechnology'.

Use of the term 'nanotechnology' retrieved the earliest of the documents examined in this study, as well as the greatest number of documents compared to those retrieved with the term 'nanoscience.' Inspec had by far the most items indexed with the term 'nanotechnology' (11,351) as well as the earliest item indexed with that term (1986). Chemical Abstracts had the greatest number of items indexed with the term 'nanoscience" (389), while SciSearch® Citation Index contained the earliest item (1991).

Five specialized nano journals were identified, three of which are indexed in *JCR* along with the journal impact factors. Only one specialized nano journal, *Nanostructured Materials*, was on ISI's list of top nano journals from 1991-2000.

A comparison of the ISI highly cited nano publications list (1991-2000) with the highly cited nanoscience and nanotechnology publications lists (2001-2004) noted:

- Two publications, *Abstracts of Papers from the American Chemical Society* and the *Journal of Nanoparticle Research*, were on both the top nanoscience and nanotechnology lists from 2001-2004.
- Two additional nano journals, *Nanotechnology* and *IEEE Transactions on Nanotechnology* were on the top nanotechnology list.
- The journal *Nature* was listed on both the ISI list (1991-2000) and the nanotechology list (2001-2004).

The differences in the top nano journal list compiled by ISI for 1991-2000 and the lists of nanoscience and nanotechnology publications compiled from data collected for this study is indicative of a shift in the publication patterns of nano research, from nano articles published in general scientific and technical journals to nano articles published in journals specializing in and focusing on nano research.

RECOMMENDATIONS FOR FUTURE RESEARCH

Since nano research does not appear to have reached its peak, future bibliometric analyses of the nano literature would be useful to track the publishing trends over a longer period of time.

A co-citation analysis and cluster mapping of authors and articles related to nanoscience and nanotechnology would be useful in understanding the growth patterns and relationships of authors, topics, and publications within the nano research arena. These techniques could be used to provide additional insight into how the field is growing and in determining the major themes in nano research.

End Notes

[1] K. Eric Drexler. 2004. Biography of K.Eric Drexler [online]. Palo Alto, CA: Foresight Institute, 2005 [cited 8 March 2005]. Available from World Wide Web: (http://www.foresight.org/FI/Drexler.html).

[2] K. Eric Drexler. *Engines of Creation: The Coming Era of Nanotechnology*. New York: Anchor Doubleday, 1986.

[3] National Research Council. 2002. *Small Wonders, Endless Frontiers, a Review of the National Nanotechnology Initiative* [online]. Washington, DC: National Academy of Sciences, 2005 [cited

15 March 2005]. Available from the World Wide Web: (http://www.nap.edu/books/0309084547/html/).

[4] Irina Stanishevskaya. "Nanotechnology and the Information Era," *Mississippi Libraries* 4 (2004): 103.

[5] W. Goffman. "Mathematical Approach to the Spread of Scientific Ideas – the History of Mast Cell Research," *Nature* 212 (1966): 449-52.

[6] Joan M. Reitz. 2004. ODLIS: Online Dictionary of Library and Information Science [online]. Portsmouth, NH: Libraries Unlimited, 2004 (cited 10 November 2004]. Available from World Wide Web: (http://www.lu.com/odlis).

[7] Linda C. Smith. "Citation Analysis," *Library Trends* 30 (Summer 1981): 83-106.

[8] Ibid., 1981.

7 Howard D. White and Katherine W. McCain. "Bibliometrics," *Annual Review of Information Science and Technology* (*ARIST*) 24 (1989): 119.

[10] Susan Davis Herring. "Journal Literature on Digital Libraries: Publishing and Indexing Patterns, 1992-1997," *College & Research Libraries* 61 (January 2000): 39-43.

[11] Nancy L. Pelzer and William H. Wiese. "Bibliometric Study of Grey Literature in Core Veterinary Medical Journals," *Journal of the Medical Library Association* 91 (October 2003): 434–441.

[12] Teresa S. Welsh. "The Literature of Telemedicine: A Bibliometric Study," *Science & Technology Libraries* 25(2004).

[13] Eugene Garfield. 1998. Mapping the World of Science [online] Philadelphia: Institute for Scientific Information®, 1998. (cited 15 March 2005). Available from World Wide Web: (http://www.garfield.library.upenn.edu/papers/mapsciworld.html).

[14] Institute for Scientific Information®, 2005. *ISI Essential Science Indicators*[SM] Special Topics: Research Front Methodology [online]. Philadelphia: ISI, 2005 (cited 15 March 2005). Available from World Wide Web: (http://www.esi-topics.com/RFmethodology.html).

[15] Brooks, Terrence A. "Core Journals of the Rapidly Changing Research Front of Superconductivity," [book chapter] *Scholarly Communication and Bibliometrics*. Thousand Oaks, CA: Sage Publications, 1990: 235-247.

[16] Brooks, Terrence A. "Literature Core Zones Adjusted by Impact Factors," *Journal of Information Science: Principles & Practice* 16 (1990): 51-57.

[17] Olle Persson. "The Intellectual Base and Research Fronts of *JASIS* 1986–1990," *Journal of the American Society for Information Science* 45 (January 1994): 31-38.

[18] Patricia A. Bianconi, Jun Lin, and Angela R. Strzelecki. "Crystallization of an Inorganic Phase Controlled by a Polymer Matrix," *Nature* 349 (1991): 315-317.

[19] M. Morimura. "Current Conditions and Future Perspectives of 3-Dimensional Nanotechnology," *Journal of the Society of Instrument and Control Engineers*.25 (May 1986): 405-11.

[20] Eugene Garfield. 1994. ISI Essay: The Impact Factor [online]. Philadelphia: ISI, 2005 (cited 15 March 2005). Available from World Wide Web: http://www.isinet.com/essays/journalcitationreports/7.html/

[21] Institute for Scientific Information®, 2005. *ISI Essential Science Indicators*SM Special Topics: Nanotechnology Top Journals [online]. Philadelphia: ISI, 2005 (cited 15 March 2005). Available from World Wide Web: (http://esi-topics.com/nano/journals/e1a.html).

Bibliography

Bianconi, Patricia A., Jun Lin, and Angela R. Strzelecki. "Crystallization of an Inorganic Phase Controlled by a Polymer Matrix," *Nature* 349 (1991): 315-317.

Brooks, Terrence A. "Core Journals of the Rapidly Changing Research Front of Superconductivity," [book chapter] *Scholarly Communication and Bibliometrics*. Thousand Oaks, CA: Sage Publications, 1990: 235-247.

Brooks, Terrence A. "Literature Core Zones Adjusted by Impact Factors," *Journal of Information Science: Principles & Practice* 16 (1990): 51-57.

Buot, F.A. "Mesoscopic Physics and Nanoelectronics: Nanoscience and Nanotechnology," *Physics Reports* 234 (November 1993): 73-174.

Drexler, K. Eric. 2004. Biography of K.Eric Drexler [online]. Palo Alto, CA: Foresight Institute, 2005 [cited 8 March 2005]. Available from World Wide Web: (http://www.foresight.org/FI/Drexler.html).

Drexler, K. Eric. *Engines of Creation: The Coming Era of Nanotechnology*. New York: Anchor Doubleday, 1986.

Garfield, Eugene. 1994. ISI Essay: The Impact Factor [online]. Philadelphia: ISI, 2005 (cited 15 March 2005). Available from World Wide Web: http://www.isinet.com/essays/journalcitationreports/7.html/

Garfield, Eugene. 1998. Mapping the World of Science [online] Philadelphia: Institute for Scientific Information®, 1998. (cited 15 March 2005). Available from World Wide Web: (http://www.garfield.library.upenn.edu/papers/mapsciworld.html).

Herring, Susan Davis. "Journal Literature on Digital Libraries: Publishing and Indexing Patterns, 1992-1997," *College & Research Libraries* 61 (January 2000): 39-43.

Institute for Scientific Information®, 2005. *ISI Essential Science Indicators*SM Special Topics: Nanotechnology Top Journals [online]. Philadelphia: ISI, 2005 (cited 15 March 2005). Available from World Wide Web: (http://esi-topics.com/nano/journals/e1a.html).

Institute for Scientific Information®, 2005. *ISI Essential Science Indicators*SM Special Topics: Research Front Methodology [online]. Philadelphia: ISI, 2005 (cited 15 March 2005). Available from World Wide Web: (http://www.esi-topics.com/RFmethodology.html).

Morimura, M. "Current Conditions and Future Perspectives of 3-Dimensional Nanotechnology," *Journal of the Society of Instrument and Control Engineers*.25 (May 1986): 405-11.

Pelzer, Nancy L. and William H. Wiese. "Bibliometric Study of Grey Literature in Core Veterinary Medical Journals," *Journal of the Medical Library Association* 91 (October 2003): 434–441.

Persson, Olle. "The Intellectual Base and Research Fronts of *JASIS* 1986–1990," *Journal of the American Society for Information Science* 45 (January 1994): 31-38.

Reitz, Joan M. 2004. ODLIS: Online Dictionary of Library and Information Science [online]. Portsmouth, NH: Libraries Unlimited, 2004 (cited 10 November 2004]. Available from World Wide Web: (http://www.lu.com/odlis).

Smith, Linda C. "Citation Analysis," *Library Trends* 30 (Summer 1981): 83-106.

Stanishevskaya, Irina. "Nanotechnology and the Information Era," *Mississippi Libraries* 4 (2004): 103-106.

Welsh, Teresa S. "The Literature of Telemedicine: A Bibliometric Study," *Science & Technology Libraries* 25(2004).

White, Howard D. and Katherine W. McCain. "Bibliometrics," *Annual Review of Information Science and Technology* (*ARIST*) 24 (1989): 119-33.

Nanoscale Research Online Resources

This list was compiled from the Oak Ridge National Laboratory Nanoscale Science, Engineering and Technology (NSET) Community of Interest Web site.

Department of Energy
http://www.er.doe.gov/production/bes/NNI.htm

Foresight Organization
http://www.foresight.org/

IBM Research
http://www.research.ibm.com/nanoscience/

Institute of Molecular Manufacturing
http://www.imm.org/

NanoLink
http://sunsite.nus.edu.sg/MEMEX/nanolink.html

Nanotechnology at NIST
http://www.nist.gov/public_affairs/nanotech.htm

NASA Nanotechnology Gallery
http://www.ipt.arc.nasa.gov/gallery.html

National Nanotechnology Initiative
http://www.nano.gov/

National Science Foundation
http://www.nsf.gov/funding/pgm_list.jsp?type=xcut

Zyvex Corporation
http://www.zyvex.com/

Academic Sites

Beckman Institute for Advanced Science and Technology
http://www.beckman.uiuc.edu/research/menhome.html

California NanoSystems Institute
http://www.cnsi.ucla.edu/

Center for Nanoscale Science and Technology
http://cnst.rice.edu/

Materials Research Science and Engineering Center
http://www.mrsec.wisc.edu/index.php

Nanoelectronics Laboratory, University of Cincinnati
http://www.nanolab.uc.edu/

Cornell NanoScale Facility
http://www.nnf.cornell.edu/

Nanoscale Science Laboratory, University of Cambridge
http://www-g.eng.cam.ac.uk/nano/

Nanoscience and Technology, University of Notre Dame
http://www.nd.edu/~ndnano/

Nanoscale Physics
http://www.physics.purdue.edu/nanophys/

NanoStructures Laboratory (NSL) at MIT
http://www-mtl.mit.edu/MTL/NSL.html

NanoStructures Laboratory (NSL) at Princeton
http://www.ee.princeton.edu/~chouweb/

Industry Sites

Center for NanoSpace Technologies, Inc.
http://nanospace.org/

Nanodata.com
http://www.nanodata.com/

Nanopowders Industries
http://www.nanopowders.com/

Nanoscale Science Department
Max-Planck-Institute for Solid State Research
http://www.mpi-stuttgart.mpg.de/kern/

Nanotechnology Industries
http://www.nanoindustries.com/

Government & Other Sites

Institute of Nanotechnology
http://www.nano.org.uk/

NASA Area Nanotechnology Study Group
http://www.amtexpo.com/nano/

Nanoscience and Technology
http://www.nanosra.nrl.navy.mil/